

KEY TO ECTOTROPHIC MYCORRHIZAE

KLUCZ DO OZNACZANIA MIKORYZ EKTOTROFICZNYCH

ОПРЕДЕЛИТЕЛЬ ЭКТОТРОФНЫХ МИКОРИЗ

Tadeusz Dominik

Katedra Ochrony Roślin WSR w Szczecinie

(Wpłynęło 2.V.1967)

Synopsis. The publication contains informations necessary for making up the research materials of mycorrhizae that are needed at identification and classification of mycorrhizae. Dichotomic keys for identification of mycorrhizae are contained in a further part of the paper. Own research are in present issue completed with research by foreign authors.

INTRODUCTION

Classification is an indispensable manner of listing the forms living in the environment of man. It enables us to know and describe the mutual relationships. Without the study of taxonomy one cannot cope with the problems of botany, zoology, geology, paleontology, mineralogy etc. Ecological research, which more and more encroaches on practical life and scientific investigations is evidently based on the taxonomy of forms i.e. on morphology. The cumbersome research of physiology and pure cultures in ecology requires a long time and is removed further into a background of laboratory research. The aim that research is to check the phenomena in ecological research. Ecological research requires classifications, which would provide a quick identification of life forms.

Mycorrhizae are organs composed of two or more organisms. They are, however, not associations, but anatomical organs, having their special life, and carrying out very important physiological functions for green plants and fungi as well. Variation in their morphological and anatomical forms is closely connected with their physiological functions. These links are so clear that even the simple anatomical research of older authors has led

to their finding the manner of life of mycorrhizas. The present research applying radioactive isotopes has just confirmed the conclusions of older authors.

The importance of mycorrhizas in the life of plants and their variation and connected with it the variation of their physiological activities, require a strict definition of these organs by plant breeders and phytopathologists and foresters as well. It often happens that finding the kind of mycorrhizas solves the riddle of root diseases and enables us to make the proper conclusion about silvicultural or manuring experiments etc.

For these reasons I have devised a classification of mycorrhizas based on morphological and anatomical features, a fact, which may often result in finding the species of a fungus concerned, which produces the fungal mantle. More commonly my classification brings about only the identification of a genus. Very many recently described, morphological links would require further research based on pure cultures in laboratory. I wonder, however, if such an attitude would be useful? If we had applied such a method then the key to mycorrhizas would be useless in ecological research, and the work on mycorrhizas would be again restricted to laboratory research and would become a subject of pure cultures and physiological work, as was the case in the past. To the forest, for example, such research is quite useless. The word "forest" does mean silviculture and ecology.

As in all other life forms, the differences in taxonomically distant mycorrhizas are well marked. The related forms of mycorrhizas, on the other hand, produce intermediate forms. These forms are difficult to classify. Research workers get accustomed to this fact. This disadvantage is also known to mycologists.

To make full use of key one should: know the anatomy of roots, anatomy of fungi, be keen in preparing mycorrhizal sections by blade and microtome, and make permanent slides. It is also necessary to find a microscopical difference between fungal prosenchyma and pseudoparenchyma (Synenchyma) (fig. 1). This difference is essential for using the key. Without the elementary knowledge of plant anatomy the key seems to be very complicated. Further anatomical features of classification are: anatomical features of fungal thalli, e.g. the occurrence of setae, cystidia, conidiophores etc. The last characteristics are based on colours. The colours play an important role in mycology e.g. the sections in the classification of *Fusarias* are based on colours and their shades. It is a known fact that in order to distinguish detailed particulars of the key the colours are necessary. My key is based not on colourshades but on several groups of colours, a feature which is easier to distinguish.

It is very important to know that the colour of mycorrhizas and that of the fungal mantle are not identical. The colour of mycorrhizas varies with the age, since it is the result of the superimposing of the colour of

fungal mantle on that of tannin layer. The colour of the fungal mantle is invariable in many mycorrhizal fungi and even in the case of very old mycorrhizas it could be exactly defined. The tannin layer, on the other hand, varies in young mycorrhizas from hyalin to bright-ochre. In the same mycorrhizas of greater age it turns from orange to brown and in very old mycorrhizas from dark brown to violet-brown colour. If the mycorrhiza is covered by a hyaline fungal mantle, then the mycorrhiza is at first hyaline or white later changes colour and becomes brown to dark-brown. In the microscopical slides, which have been prepared by cutting with a razor blade (15—25 μ in thickness), at the magnification of about 400 x hyaline fungal mantle may still be found. Hence the diagnostic feature is not the colour of mycorrhizas but the colour of fungal mantle. This colour on living mycorrhizas obtained straight from soils, may be distinguished — after some training — by using a 10—20 x pocket lens.

Usually the roots collected for mycorrhizas research should be pickled in methyl alcohol. Such a fixative is satisfactory and simple in use. It changes, however, certain colours. It is, therefore, necessary to check the roots by using a pocket lens and note the colours of mycorrhizas, before putting the roots in alcohol. This procedure is especially important for the following colours: white, cream, pink to crimson, violet, pale pinkish violet colour etc. These colours vanish immediately after the specimens have been dipped in alcohol.

When defining such colours which do not undergo any change under the microscope in slides apochromatic objectives should be used.

For identification mature mycorrhizas ought to be used. Young and very old mycorrhizas may cause non-trained workers much doubt. They also may lack certain characteristics, e. g. setae, cystidia etc. or these features already might have been lost.

Mycorrhizal sections which have been used for research and classification, should be pickled in Amann's lactophenol.

GLOSSARY

Clamp connection: a bridge-like, hyphal connection characteristic of the secondary (binucleate) mycelium of the Basidiomycetes.

Cystidium: a sterile structure in the hymenium or on the other part of hymenophor.

Hymenium: a layer of asci or basidia; „sensu largo” a layer of cystidia or conidiophores too.

Pseudoparenchyma: a type of plectenchyma (fungal tissue) consisting of oval or isodiametric cells, the component hyphae having lost their individuality.

Prosenhyoma: a type of plectenchyma consisting of hyphae of different length, which haven't lost their individuality; or when the hyphal elements are seen to be hyphae.

Sclerotium: a hard resting body, resistant to unfavorable conditions which may remain dormant for long periods of time and germinate upon the return of favorable conditions. Sclerotium is build of pseudoparenchyma scleremchymatic (pseudosclerenchyma).

Seta: a bristle-like hair.

Sterigma: a small hyphal branch of structure which supports a conidium or a basidiospore.

Synnema: (pl. synnemata) a group of hyphae or conidiophores cemented together and forming an elongated structure; vegetative synnemata: synnemata without spores.

Synenchyma: = pseudoparenchyma.

Synenchymatic: = pseudoparenchymatic.

DICHOTOMIC KEY TO SUBTYPES OF ECTOTROPHIC MYCORRHIZAE

- | | |
|---|----|
| 1 Fungus mantle (hyphal sheat) simple, root simple or ramifying | 2 |
| — Fungus mantle two layers. Mantle enveloping single or ramifying roots or two or more rootlets which grow together (have simple mantle each) at form tubers of different sizes. The tubers are enveloping in own independent mantle each | 10 |
| 2 Mantle prosenchymatic (felt-like) | 3 |
| — Mantle pseudoparenchymatous (synenchymatic) | 7 |
| 3 Mantle loosely woven, enveloping the short-root like a felt with gaps in it. There are often strands of mycelium. These strands are not densely woven forming no real rhizomorphs | |

Subtype A

- | | |
|--|---|
| — Mantle densely and regularly woven, without any gaps, sometimes appearing to be pseudoparenchymatous | 4 |
| 4 Surface of the fungus mantles smooth or only covered with very short and mild nap of hyphae | |

Subtype B

- | | |
|--|---|
| — Surface of the mantly covered with hyphae of different structure: bristles (setae), sterile tubes (cystidia), rhizomorphs, very large nap of hyphae etc. | 5 |
|--|---|

- 5 Mantle covered with numerous rhizomorphs or with vegetative synnemata which under the binocular looks like a veil or with large nap of hyphae

Subtype C

- Mantle covered with other structures 6

- 6 Mantle covered with bristles. These are of different structure. Between bristles may be a number of cystidia

Subtype D

- Mantle covered with sterile tubes (cystidia) only which may been arranged in a palisade or in nests

Subtype E

- 7 Surface of the mantle smooth or only with single and isolated hyphae

Subtype F

- Surface of mantle covered with numerous hyphae which under the binocular look like root hairs or with bristles or rhizomorphs 8

- 8 The hyphae which grow out of mantle are stiff and their ends are never pointed; generally the whole mantle is almost black or dark brown (rarely yellow-brown)

Subtype G

- Mantle covered with soft hyphae or with bristles 9

- 9 The hyphae which grow out of the mantle are very soft. They often form loose hyphal strands or there is another layer of loose hyphal strands around the synenchymatous layer

Subtype H

- On the surface of the synenchymatous mantle there are bristles of different quantity and quality

Subtype I

- 10 Mycorrhizae only as simple fungus roots 11

- Mycorrhizae (two or many) are grown together (coalescent) in a compound, tuberlike. Every short root has its own mantle and a whole tuber has a common mantle. The two kinds of mantles have the same structure or different structure

Subtype J

- 11 The outer layer of mantle is prosenchymatous 12
 — The outer layer of mantle is synenchymatous 13
 12 The outer layer of mantle is dark brown. The inner layer has a different colour and different structure. One fungus is superimposed on the other fungus

Subtype K

- The outer layer and the inner layer of mantle have the same colour but a different structure. Both layers are formed by the same fungus

Subtype II

- 13 The surface of the outer layer is composed of elliptical brown or black-brown cells. The inner layer is colourless, felt-like and densely woven. The structure of the mantle looks like that of perithecia

Subtype L

- The outer layer of the mantle is dark-brown. The inner layer has different colour and different structure. One fungus is superimposed on the other

Subtype K

KEY TO GENERA OF ECTOTROFIC MYCORRHIZAE

This part of the key to ectotrophic mycorrhizae is open for completions. All new genera of mycorrhizae may be located in following keys and become suitable letter-symbols.

Subtype A

- | | | |
|---|---|----------|
| 1 | Fungus mantle colourless or greyish | Genus Aa |
| 2 | " " cream-coloured | " Ab |
| 3 | " " yellow to yellowish | " Ac |
| 4 | " " lemon or sulphur-coloured | " Ad |
| 5 | " " light ochre | " Ae |
| 6 | " " brownish to brown | " Af |
| 7 | " " dark brown to greenish-black | " Ag |
| 8 | " " black-blue (ink) coloured | " Ah |
| 9 | " " poisonous-green (gift-grün) | " Ai |

Subtype B

- | | | |
|---|---|----------|
| 1 | Fungus mantle colourless or greyish | Genus Ba |
| 2 | " " cream coloured | " Bb |
| 3 | " " yellow to yellowish | " Bc |

4	"	"	light ochre	"	Bd
5	"	"	rose-coloured to pink	"	Be
6	"	"	vivid brown	"	Bf
7	"	"	dark-brown to black-brown	"	Bg

Subtype C

1	Fungus mantle colourless to white or greyish	Genus Ca
2	" " cream-coloured	Cb
3	" " yellow to yellowish	Cc
4	" " light ochre	Cd
5	" " pink to carmin	Ce
6	" " dark brown to light brown	Cf
7	" " dark grey (under microscope: light greenish)	Cg

Subtype D

- 1 Pseudohymenium (non typic hymenium) with bristles only 2
- Pseudohymenium with bristles and cystids 3
- 2 Fungus mantle under microscope colourless, covered with short bristles, the length of which is never longer than ten times the width of the base. The bristless are hyaline

Genus Da

- Fungus mantle under microscope colourless, covered with very long bristles which are straight or not straight. These bristles are colourless or greyish

Genus Db

- 3 Bristless and fungus mantle dark brown. Bristles curved, flexuous, thin-walled, soft-narrowed to the tip, with rounded ends. Between bristles are brown hyphae with clamps

Genus Dc

- Bristles not dark brown 4
- 4 Bristles soft narrowed to the tip, *rounded* of the ends . . . 5
 - Bristles soft narrowed to the tip, *pointed* on the ends, thin-walled, colourless. Between bristles are two types of cystids: cheilocystids so as by *Nematoloma* sp. with vesicle-like inflated tips and lamprocystids so as by *Cantharellus* sp. with verrucose walls. The two types of cystids are colourless. Fungus mantle yellow-grey to brown

Genus De

- 5 Pseudohymenium with bristles and with one type of cystids only. Bristles are curved, thin-walled, inflated bottle-like at the

base, soft narrowed to the tip, flabby, yellowish to colourless. Cystids bottle-like inflated, short, with vesicle-like inflated tips

Genus Dd

- Pseudohymenium with bristles and two types of cystids. Bristles bow-like curved, thin-walled, fleebly inflated at the base, soft narrowed to the tip, *rounded* on the ends. Cystids: cheilocystids so as by *Nematoloma* sp., feebly inflated at the base and vesicle-like inflated on the tips, thin-walled; lamprocystids so as by *Cantharellus carbonarius*, with verrucose walls, feebly inflated at the base. Verrucae on total length of lamprocystids! Cystids in general hyaline to brownish. Fungus mantle yellowish-brown

Genus Df

Subtype E

- 1 Pseudohymenium on the fungus mantle with cystids only 2
- Pseudohymenium on the fungus mantle with cystids, basidia-like hyphae or with conidiophores 4
- 2 Cystids bottle-like inflated at the base, vesicle-like inflated on the tips or with other ornaments on the tips. Fungus mantle yellowish-grey. Single hyphae between the cystids hyaline

Genus Ea

- Cystids generally not inflated at the base 3
- 3 Cystids generally not inflated at the base or rarely very feebly inflated, with vesicle-like formations on the tips (so as a flame of a wax-candle) so as by *Russula virescens* or by other *Russula* sp. of this group

Genus Ed

- Cystids never inflated at the base, pear-shaped so as the pileocystids of *Polyporellus varius*. The mycorrhizae have the same perfume as this fungus. Fungus mantle olive brown. Cystids olive-brown, thin-walled, smooth

Genus Ee

- 4 Pseudohymenium with cystids without ornaments on the tips, but between them are basidia-like hyphae with 2—3 spores (conidia) without sterigmata

Genus Eb

- Pseudohymenium with cystids and conidiophores of the *Rhino-trichum* type. Conidia ellipsoidal, hyaline, one-celled (con-

tinous). Conidiophores simple, hyaline, bearing at tip and laterally the short peg-like sterigmata

Genus Ec

Subtype F

- | | | |
|----|---|----------|
| 1 | Fungus mantle colourless or white-grey | Genus Fa |
| 2 | " " cream coloured | " Fb |
| 3 | " " yellowish to yellow | " Fc |
| 4 | " " light ochre | " Fd |
| 5 | " " pink to red | " Fe |
| 6 | " " tawny | " Ff |
| 7 | " " brown | " Fg |
| 8 | " " black | " Fh |
| 9 | " " olive-grey | " Fi |
| 10 | " " external layer yellow, internal layer of
mantle violet | " Fj |

Subtype G

- 1 Colour of the mycelium is black, seldom brown-black or dark violet-brown. The surface of the mantle is covered with hyphae which are straight and smooth, projecting at right angle from the surface. Sometimes the mantle is covered with hyphal strands (vegetative synnemata)

Genus Ga

- 2 Colour of the mycelium is tawny (bronze) to light brown, the surface of the mantle is smooth or covered with yellowish hyphae, projecting at right angle from the surface, not straight

Genus Gb

Subtype H

- | | | |
|----|---|----------|
| 1 | Fungus mantle colourless or white-greyish | Genus Ha |
| 2 | " " cream-coloured | " Hb |
| 3 | " " yellowish to yellow | " Hc |
| 4 | " " light ochre | " Hd |
| 5 | " " pink to vivid red | " He |
| 6 | " " tawny | " Hf |
| 7 | " " brown to dark brown | " Hg |
| 8 | " " light citron coloured | " Hh |
| 9 | " " yellow to brown with single spinulae | " Hi |
| 10 | " " dark violet-brown | " Hj |
| 11 | " " blue (bleu de ciel) | " Hk |

Subtype I

- 1 Bristles star-like ramifying, pear-like or vesicle-like inflated, with 3 — many pointed ramifications (Fontana 1962, Boullard 1966)

Genus II

- Bristles not star-like ramifying 2
 2 Bristles abundant ramifying so as commonly by hyphae, hyaline, cover densely the surface of fungal mantle so as a halo; dichotomically bifurcated bristles widely spreading from the surface of synenchyma (Boullard 1966)

Genus Im

- Bristles not ramifying or very rarely with single ramifications 3
 3 Bristles colourless or fast so (hyaline) 4
 — Bristles distinctly coloured 8
 4 Bristles on the tip pointed, stiff. Fungus mantle yellowish brown. Bristles continuous or with single septa

Genus Ia

- Bristles on the tip rounded or vesicle-like inflated 5
 5 Bristles one-celled (continuous) 6
 — Bristles many-celled (with septa) 7
 6 Bristles vesicle-like inflated on the tip, straight, stiff, thin-walled. Fungus mantle tawny to brownish

Genus Ig

- Bristles not inflated vesicle like on the tip, but rounded to very feebly inflated, flexuous, flabby, hyalin. Fungus mantle hyalin to grey

Genus Ic

- 7 Bristles with one septum on the base, straight or bow-like curved, thin-walled, rounded on the tip, feebly inflated at the base, hyaline or yellowish at the base. Fungus mantle yellowish-brown to brown

Genus Ih

- Bristles many-celled with the last element very much mace-like inflated (not always), sometimes ramifying. On the several septa of bristles are clamps. Fungus mantle dark brown

Genus Ie

- 8 Bristles thick-walled 9
 — Bristles thin-walled 11

- 9 Fungus mantle hyaline. Bristles with septa, stiff, pointed, smooth, light brown to brown at the base, clear up to the tip and becomes nearly hyalin on the tip. Self basis is inflated and resembling the ambient cells of synenchyma of fungal mantle in the shape

Genus Ik

- Fungus mantle coloured 10

- 10 Fungus mantle grey-yellow. Bristles light yellow, bow-like curved, at the base bulb-like inflated, pointed at the tip or rounded. Yellow hyphae between the bristles have clamps connections

Genus If

- Fungus mantle dark-brown to violet-brown (very dark). Bristles straight or bow-like curved, feebly coloured, pointed (awl-shaped)

Genus Ib

- 11 Bristles with one to two septa, not inflated at the base pointed or rounded on the tip, brown-coloured, thin-walled. Fungus mantle very dark brown

Genus Id

- Bristles one-celled, bottle-like inflated at the base ampullaeformis, thin-walled, brown. Fungus mantle violet-brown, very dark

Genus Ij

Remark: Genus Ij was on red-fir wrong as Genus Id described by Dominik (1961).

Subtype J

- 1 Fungus mantle hyaline, white-greyish or cream-grey

Genus Ja

- Fungus mantle (exterior) tawny to brown, fungus mantle interior other colour, always light coloured. Hyphae of exterior mantle without septa, thick-walled, not developes in culture media. These mycorrhizae are composed by two or many species of fungi

Genus Jb

Sybttype K

- 1 The outer layer of fungal mantle is formed by dark brown hyphae (burnt siena). The hyphae are neither stiff nor thick. This fungus is *Mycelium radialis atrovirens*. The inner layer is of a different structure and colour

Genus Ka

- 2 The outer layer of fungal mantle is formed by violet or black brown hyphae, which are stiff and thick, becoming synen-
- chymatous. This fungus is *Cenococcum graniforme*. The inner layer is of different structure and colour

Genus Kb

- 3 All features of the fungal mantle are like those of number two, but the hyphae are smaller than the hyphae of *Cenococcum graniforme*. There are often nests and pieces of synenchyma in the fungal mantle

Genus Kc

Subtype L

The surface of the outer layer of fungal mantle is formed by elliptical cells and brown or black-brown bristles, which are stiff and pointed on the ends. The inner layer is colourless and felt-like and of a densely woven structure. The structure of fungal mantle looks like that of the perithecia

Genus La

KLUCZ DO OZNACZANIA MIKORYZ EKTOTROFICZNYCH**Streszczenie**

Wstęp do niniejszej publikacji zawiera najpotrzebniejsze uwagi na temat budowy mikoryz oraz na temat metodyki oznaczania mikoryz według załączonego klucza.

Wydanie pracy w języku angielskim jest niezbędne, gdyż tłumaczenia z polskich wersji przez autorów zagranicznych zawierają liczne błędy merytoryczne, zniekształcające w sposób niedopuszczalny sens tekstu polskiego.

Tłumaczenie całego klucza na język polski byłoby niecelowe, gdyż istnieją już wersje polskie bardzo zbliżone do ostatecznej. Streszczenie zaś klucza jest niemożliwe.

W niniejszej wersji przybyły opisy nowych form mikoryz ektotroficznych opisanych przez autorów zagranicznych i odkrytych przez autora w lasach czechosłowackich w 1966 r.

ОПРЕДЕЛИТЕЛЬ ЭКТОТРОФНЫХ МИКОРИЗ

Краткое содержание

Введение в настоящую публикацию содержит самые необходимые замечания на тему строения микориз, а также на тему методики определения микориз согласно приложенному определителю.

Издание на английском языке является необходимым, так как переводы из польского зарубежными авторами содержат многочисленные существенные ошибки, искажающие недопустимым образом смысл польского текста.

Перевод определителя на польский язык полностью был бы тоже нецелесообразным, так как имеются польские версии, очень приближенные к конечной.

К настоящей версии прибавлены описания новых форм эктотрофных микориз, описанных зарубежными авторами и обнаруженные автором в лесах Чехословакии в 1966 году.

REFERENCES

1. Boullard B.: Un nouveau sous-type de mycorrhizes ectotrophes decouvert sur des racines d'arbres croissant en Haute-Normandie. Rev. Soc. Sav. Haute-Normandie — Sciences 1966; Nr 41, pag. 17—20.
2. Dominik T.: Projekt nowego podziału mikoryz ektotroficznych opartych na cechach morfologiczno-anatomicznych. Roczniki Nauk Leśnych 1956; Vol. 14, p. 223—245.
3. Dominik T.: Klucze do oznaczania mikoryz. (Key for mycorrhizae determination). Zesz. Nauk. Wyż. Szkoły Roln. Szczecin 1961; Nr 5, p. 63—104.
4. Dominik T.: Synopsis of a new classification of the ectotrophic mycorrhizae established on morphological and anatomical characteristics. Mycop. et Mycol. Appl. 1959; Vol. XI: 4, p. 359—367.
5. Dominik T.: Studium o mikoryzie. (Studies on Mycorrhizae) Folia forestalia Polonica. Zesz. 5 Seria A, p. 1—160.
6. Dominik T.: Studium nad mikotrofizmem świerka pospolitego — *Picea excelsa* (Lam.) Lk w Polsce. (Studien über den Mykotrophismus der Fichte — *Picea excelsa* (Lam.) Lk in Polen.) Prace Inst. Bad. Leśn. 1961; Nr 209, p. 59—102.
7. Fontana A.: Ricerche sulle micorrhize del genere *Salix*. Allionia 1962; p. 67—85.
8. Mejstrik V., Dominik T.: Mykorrhiza u buku (*Fagus silvatica* L.) na různých stanovištích v ČSSR. Sborník Vědeckého lesnického ústavu Vysoké školy zemědělské v Praze Vol. 10, 1967, pp. 317—340.